The best test of the relations in density between molten and solidified rock is apparently to compare the density of the rock just before fusion, or at least near that point, with the density of the same rock after melting. This would give a comparison between the crystalline and liquid states, while the usual method only affords a comparison between the liquid and the glassy or semi-glassy states. It would also save any error arising from cells in the cooled rock, if a solid mass was chosen in the first place. Again the fresh unaltered varieties of a rock should be chosen instead of such old and altered ones as those usually experimented upon.

In all discussions relating to the question of the liquidity of the earth's interior, it is to be borne in mind that the chief portion of our knowledge of the properties of liquids is derived from the study of water, a mobile liquid—while liquid rock, as lava or melted iron, is viscous, and its laws and properties may on experiment be found to differ considerably from those of water, under like conditions. Also in these solids the passage from the solid to the liquid state or the reverse is not abrupt as is the case with water, for every grade of viscosity exists between the normal solidity and the approximately perfect liquid condition. This is especially the case with iron and seems to be so for the common rocks.

(*To be continued.*)

——:o:——

THE TERTIARY MARSUPIALIA.

BY E. D. COPE.

SINCE Cuvier discovered an opossum in the gypsum of Paris, the knowledge of the Marsupials of the Tertiary periods of Europe and North America has been gradually extended. In Europe they have been traced to the Middle Miocene, when they disappear from that continent. In North America we know them from Oligocene beds (White River), when they disappear, and are only known as yet thereafter as members of the existing fauna. Descending the scale we have them in the Laramie in America and Jurassic in America and Europe, and in the Trias in South Africa. Whether the Triassic Mammalia of the northern hemisphere belong to this order or not is uncertain. Under the head of Creodonta[1] I have discussed the marsupial resemblances of

[1] NATURALIST, March, April and May, 1884.

that division of Eocene mammals, showing that although their dentition is sometimes that of the carnivorous division of the marsupial order, they cannot be placed with them.

The extinct marsupials belong to three types, as distinguished by the form of their superior molar teeth. These are trituberculate, quadrituberculate or multituberculate. To the first division belong the carnivorous types, or Sarcophaga of Owen; to the second the kangaroos and the wombats, to which Owen's name of Poëphaga may be applied.[1] The third division is entirely extinct, and is characterized by having at least three longitudinal series of tubercles in its superior molar teeth. To this suborder I apply the name of Multituberculata. The suborder Sarcophaga includes the opossums, and in North America the single extinct genus Peratherium [2]Aymard. This is also the genus which is found in the Oligocene and Miocene of France. It differs from Didelphys (the true opossum) in the non-inflection of the angle of the mandible. Otherwise the two genera are very similar, agreeing in the number (eight) of the inferior incisor teeth. Five species have been found in the White River beds of Colorado. The largest of these, *P. fugax* Cope (Fig. 1), had the skull as large as that of a mole (*Scalops aquaticus*). The smallest, *P. huntii* Cope, does not exceed a small shrew in dimensions.

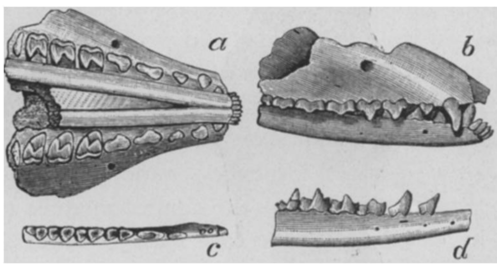


FIG. 1.—*Peratherium fugax* Cope, from the White River beds of Northeastern Colorado, twice natural size. Fig, *a*, anterior part of skull from below; *b*, do. right side; Fig. *c*, part of right mandibular ramus, with all the molars or their alveoli, from above; *d*, do., from the right side.

Of Poëphaga no extinct forms have been found in North America.

The Multituberculata include three families, which differ as follows:

Fourth superior premolar (at least) like true molars.............. *Tritylodontidæ.*
Fourth premolars (and probably others) more simple than first true molars *Polymastodontidæ.*
Fourth premolars (and often others) developed into flat cutting blades *Plagiaulacidæ.*

[1] Owen places the Phascolomyidæ in a distinct suborder, but, as it appears to me, without sufficient reason. [2] Bulletin U. S. Geol. Survey Terrs, V, No. 1, p. 45.

In all three of these families the incisor teeth are in reduced numbers, and are constructed on the rodent type, with an external band of enamel. They thus approach the genus Phascolomys (wombat), one of the Poëphaga of the existing Australian fauna. The genus Tritylodon (Fig. 2), recently described by Owen, is from the South African Trias. It is a remarkably specialized form, considering its geological antiquity. Its formula above is, I. 2; Pm. 4; M. 3. The lower jaw is unknown. The median incisors are developed at the expense of the laterals, and are separated by a wide interspace. There is also a maxillary diastema. The molars and last premolars all support three rows of shortly conic tubercles (Fig. 7 *h*). The genus Stereognathus

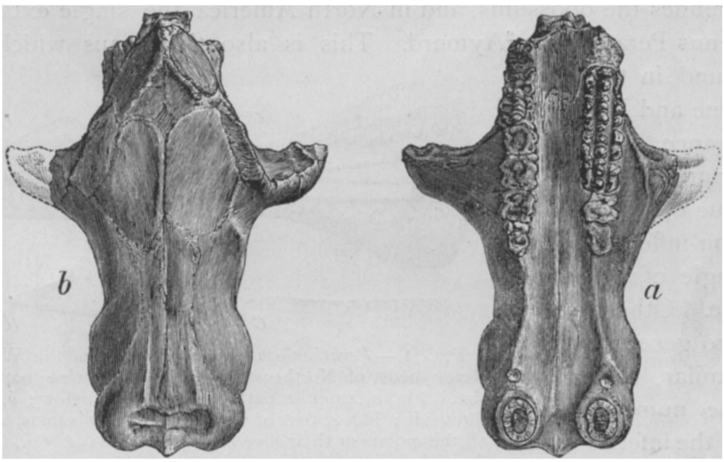


FIG. 2.—*Tritylodon longævus* Owen, anterior part of skull, natural size; from the Triassic beds of S. Africa. Fig. *a*, from below; *b*, from above. From Owen, Quart. Journ. Geol. Society, 1884, p. 146.

Charlesw., includes species from the English Oölite. The known molars have three longitudinal rows of crescentic tubercles (Fig. 7 *b*). The species are no larger than a small shrew, while the skull of *Tritylodon longævus* is as large as that of a gray fox. Information as to the structure of the skeleton of these remarkable forms has not yet been obtained.

There is but one genus of the Polymastodontidæ, the Polymastodon Cope. It is known from three species, all from the Puerco Eocene of New Mexico. The largest, *P. taoënsis* Cope, has bones equal in size to those of the large kangaroo, *Macropus major*. The jaw of the smallest species, *P. foliatus* (Fig. 5), is as large as that of *Hyrax capensis*; that of the third species, *P. fissidens*

Cope, is intermediate in dimensions, and the dentition has some well-marked peculiarities. The characters of the skeleton, so far as known, are derived from the *P. taoënsis* (Figs. 3 and 4).

The angle of the lower jaw is inflected, and the dental foramen is at the anterior apex of a large fossa, as in most marsupials. There are but two true molars in each jaw, and a single simple premolar, below. The condyle of the humerus presents characters shared by Meniscoëssus of the Laramie, which are found in lizards. There is a strong and thick intertrochlear ridge in front, which is so swollen at one side of the middle line as to resemble the condyle

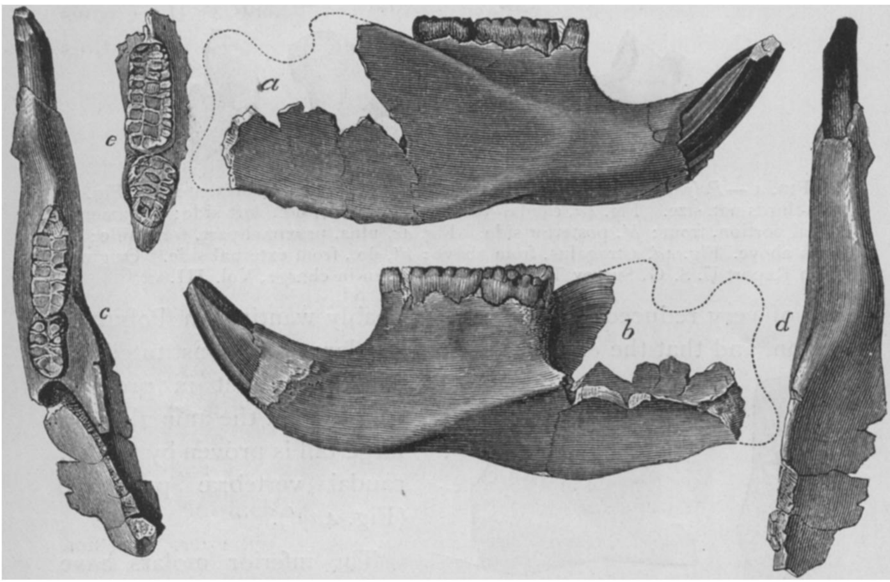


FIG. 3.—*Polymastodon taoënsis* Cope, jaws, two-thirds nat. size; from the Lower Puerco beds of New Mexico. Fig. *a*, right mandibular ramus right side; *b*, do., internal side; *c*, do., from above; *d*, from below. Original, from Report U. S. Geol. Survey Terrs., F. V. Hayden in charge, Vol. III.

of a femur. The trochlea for the coronoid process of the ulna, on the posterior side, is narrowed so as to suggest a rotular groove (Fig. 4*b′*). The humeral cotylus of the ulna is adapted to this condyle by a flare on each side (Fig. 4*c*). The astragalus is without trochlea, as in most Puerco Mammalia, and the trochlear portion is gently convex anteroposteriorly. The head is much narrowed, and has a narrow navicular face which is convex in only one, the vertical, direction. On its outer side it bears a large flat facet for the cuboid bone (Fig. 4*d′*). This form is much like that of the kangaroos. It shows that the peculiar structure of the posterior foot of the Macropodidæ already existed at this early day, though

perhaps in not quite so specialized a condition as at the present time. The form of the astragalus shows that the internal digits

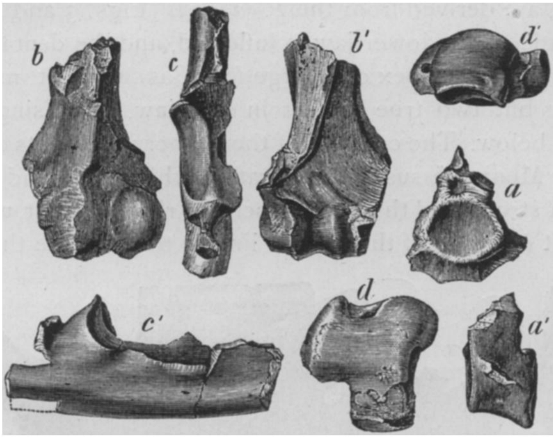


FIG. 4.—*Polymastodon taoënsis* Cope; parts of individual represented in Fig. 3, two-thirds nat. size. Fig. 4*a*, caudal vertebra, front; *a'*, do., left side; *b*, humerus, distal portion, front; *b'*, posterior side. Fig. 4*c*, ulna, proximal part, front side; *c'*, from above. Fig. 4*d*, astragalus, from above; *d'*, do., from external side. Original, from Report U. S. G. Survey Terrs., F. V. Hayden in charge, Vol. III.

are of very reduced size, the first probably wanting, in Polymastodon, and that the external digits were large and constituted the principal agent in progression. That the animal had a large tail is proven by the few caudal vertebræ preserved (Fig. 4*aa'*).

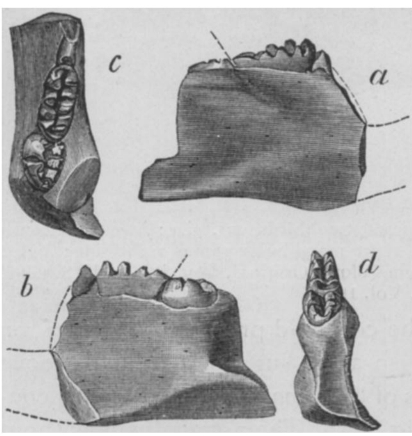


FIG. 5.—*Polymastodon foliatus* Cope; part of right mandibular ramus, natural size, Fig. 5*a*, right side; *b*, left do.; *c*, from above; *d*, posterior view, showing masseteric and dental fossæ. From the Lower Puerco of New Mexico. Original, from the Report of the U. S. Geol. Survey Terrs., F. V. Hayden, Vol. III.

The inferior molars have but two rows of tubercles, and the penultimate is much larger than the last one. The former tooth looks a good deal like a reduced last inferior molar of some species of Mastodon. The family was of herbivorous habits, and is probably the ancestral type of the kangaroos. The discovery of this remarkable genus in our Lower Eocene beds marks an important advance in the knowledge of the origin

of one of the most interesting of living forms. On the other hand, the Polymastodontidæ may well have derived their origin from the Tritylodontidæ, which were also of herbivorous or granivorous habits. The family of the Plagiaulacidæ[1] is one of the most peculiar among those of the Mammalia, whether we consider its structure or its relations to geological time. Commencing in the Jurassic period, it persisted through the Cretaceous to the Eocene. It then disappeared from view to remind us once more of its existence by its probable descendant, the extraordinary pouched lion of the Pliocene period of Australia, *Thylacoleo carnifex* Owen (Fig. 9). The family exhibits the usual successional relation of its component genera. In this respect it repeats what I have already pointed out as a law of succession in placental Mammalia,[2] a reduction in the number of premolar teeth. The following table exhibits these relations:

I. Tubercles of superior molar crescentic.
Fourth premolar serrate, not ridged.................................*Meniscoëssus.*
II. Tubercles of molars subconic.
a. Four compressed premolars below.
Premolars serrate, not ridged.................................*Ctenacodon.*
Premolars ridged and serrate.................................*Plioprion.*[3]
aa. Three compressed premolars.
Premolars ridged.................................*Plagiaulax.*
aaa. Two premolars.
Fourth premolar ridged.................................*Ptilodus.*
aaaa. One premolar.[4]
Fourth premolar ridged.................................*Neoplagiaulax.*
Fourth premolar smooth.................................*Liotomus.*[5]

Of these seven genera but nine species are thus far known. Ptilodus and Ctenacodon have two species each; and each of the others but one. Ctenacodon, Plagiaulax and Plioprion are Jurassic; Meniscoëssus is Cretaceous, and the remaining three genera are Eocene Tertiary. The American genera are Ctenacodon Marsh (Fig. 7 *g*), Meniscoëssus Cope, and Ptilodus Cope. The first named is the most generalized of the family. The *Meniscoëssus conquistus* Cope, has the distinction of being the only known mammal of the Cretaceous period.

[1] This family is the equivalent of Marsh's "order" Allotheria.
[2] Bulletin U. S. Geol. Survey Terrs., VI, p. 168.
[3] Gen. nov., type *Plagiaulax minor* Falconer.
[4] Number unknown in Liotomus.
[5] Gen. nov., type *Neoplagiaulax marshii* Lemoine.

The genus first discovered was the Plagiaulax of Owen, of which the typical species was found in the Purbeck bed of the Isle of Wight, England. It was made the subject of a memoir by Falconer. Ctenacodon was next discovered in the Jurassic of Wyoming by Marsh in 1879. In 1880 Dr. Lemoine discovered the first Tertiary representative of the family, and in 1882 named it *Neoplagiaulax eocænus* (Fig. 6). In November, 1881, I described the first American Tertiary form, which was discovered in the Puerco beds of New Mexico, under the name of *Ptilodus*

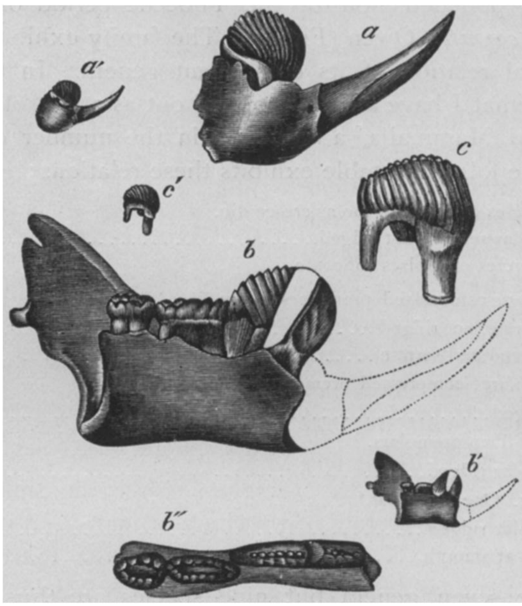


FIG. 6.—*Neoplagiaulax eocænus* Lemoine, from the Cernaysian beds of Reims, France; mandibular rami and teeth of three individuals which are represented by the letters *a*, *b* and *c*. Figs. *a*, *b*, and *c*, much enlarged. Figs. *a'*, *b'* and *c'*, natural size. Fig. *b'''*, from above. From Lemoine, Bulletin de Soc. Geol. de France, 1882, p. 249.

mediævus (Fig. 8). Its presence in that formation, together with various other associated types, proved the near homotaxy of the beds explored by Dr. Lemoine near Reims with those of New Mexico.[1]

Up to this time the great Cretaceous period had remained a blank in the history of Mammalian life. European palæontologists had examined the fresh-water beds of this period for mammalian remains without success. Among them, the gifted Kowalev-

[1] See the NATURALIST, 1883, p. 870.

sky, too soon lost to science, spent much time in the south of France among the formations which most nearly represent the American Laramie formation, but found no Mammalia. It remained for Mr. Wortman to crown a series of successful expeditions by the discovery of the *Meniscoëssus conquistus* in the Laramie formation of Dakota, its loose teeth being found mixed with the teeth of dinosaurs and scales of gar-fishes. The characters of the molar teeth are highly appropriate to the geological age of the genus, the superior molar resemblinhg bot that of the Jurassic Stereognathus and the Eocene Polymastodon.

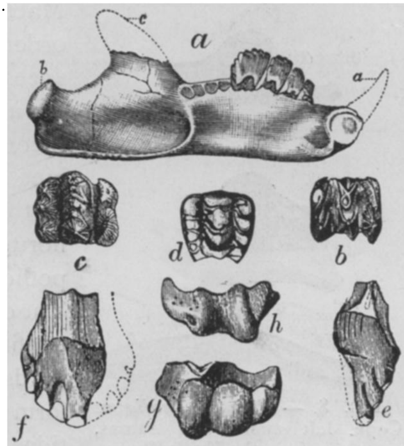


FIG. 7.—Fig. *a*, *Ctenacodon serratus* Marsh, $\frac{3}{1}$ nat. size, from Marsh. Fig. *b*, molar of *Stereognathus oöliticus*, $\frac{3}{1}$, from Owen. Fig *c*, right fourth upper molar of *Tritylodon longævus*, from Owen, $\frac{3}{1}$. Figs. *d–f*, *Meniscoëssus conquistus* Cope, $\frac{3}{2}$ nat. size. Fig. *d*, superior molar; Figs. *e–f*, superior fourth premolar[1]; *g*, humeral condyles of a smaller species with jaw, found with the *Meniscoëssus*.

I have shown that the cutting tooth of the lower jaw in the genera with but one such tooth, as Ptilodus and Thylacoleo, is the fourth premolar;[2] while the similar tooth in the existing kangaroo-rats, with which it has been compared, is a third premolar. In the living genera the fourth premolar resembles a true molar. It is necessary to remember this fact in the attempt to ascertain the phylogeny of the Multituberculata. This is not an entirely easy task, owing to the questions which arise as to the origin of the cutting premolars themselves. In general it is true of Mammalia that simple premolars precede the complex in time; but an exception to this rule is to be seen in the tritubercular superior sectorial tooth of some Creodonta and Carnivora. Whether the premolars of this family are primitive or derivative is not as yet known. If they be primitive they may be direct modifications of the serrate teeth of the herbivorous Dinosauria or Theromorpha. The complex character of the premolars in the older Tritylodon suggests the possibility of the other alternative. The general history of the Plagiaulacidæ con-

[1] This tooth may possibly belong to a Saurian.
[2] NATURALIST, 1882, p. 521.

firms the theory of derivation from complex premolars, and we observe in the later form, Thylacoleo, a simplification of the true molars also. The molariform fourth premolars in the existing Macropodidæ confirm this view. In order to connect these latter with the ancestral form of the Plagiaulacidæ, on a former occasion, I posited a theoretical form which should combine three of the cutting premolars of the extinct family with the molariform fourth premolar of the Macropodidæ. This I named Tritomodon.[1] The discovery of Tritylodon has added confirmation to this view, at least as regards the prior existence of the molariform premolars. The Polymastodontidæ were probably derived from the Tritylodontidæ by the usual process of reduction of number of teeth and specialization of those that remain. Thylacoleo[2] must be regarded as the type of a family distinct from the Plagiaulacidæ, since it has but one true molar tooth in the upper jaw. The composition of that tooth is unknown, so that it is not certain whether the family Thylacoleontidæ must be placed in the Multituberculata or Sarcophaga. That it is a direct descendant of the Plagiaulacidæ I think there is no doubt. The following phylogenetic scheme is similar to one I published in the NATURALIST, 1882, p. 521, with some addition, and the removal of Polymastodon (Catopsalis) from the Plagiaulacidæ:

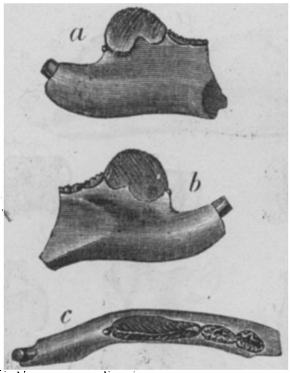
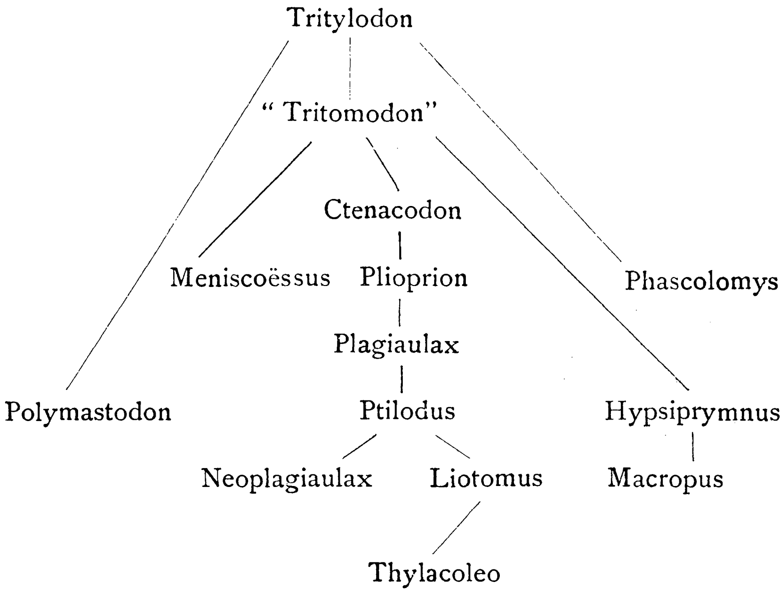


FIG. 8. — *Ptilodus mediævus* Cope, left mandibular ramus, nat. size; from the Upper Puerco beds of New Mexico. Fig. *a*, external side; *b*, internal do.; *c*, superior view, $\frac{3}{2}$ nat. size. Original, from Report U. S. Geol. Survey Terrs., III, F. V. Hayden in charge.

[1] NATURALIST, 1882, p. 521.

[2] Owen, Quar. Journ. Geol. Society, London, 1883.



It appears from the preceding considerations that the dentition of the implacental Mammalia has had a history independent of that of the placental series so far as regards the herbivorous types at least. I have shown that the primitive types of the placental series were tritubercular, and then quadritubercular, and then crested. In the herbivorous marsupials, on the contrary, we commence with multitubercular forms, and it is yet an open question whether these have had a quadri- and tritubercular ancestry or not.

The Plagiaulacidæ of the Jurassic period are of very small size, none of them exceeding in dimensions the house mouse. The same is true of the species of the Eocene period hitherto found in Europe. The American species are larger, the *Ptilodus mediævus* equaling probably the Norway rat (Fig. 8), while the *P. trovessartianus* is one-third smaller. The *Meniscoëssus conquistus* is still larger, equaling about the *Polymastodon foliatus* (Fig. 7). The arrangement of the crests of the fourth premolar in the species of Plagiaulacidæ differs as follows: In Plagiaulax, Plioprion and Neoplagiaulax this tooth is grooved. In Ptilodus the grooves have become so wide (Fig. 8) that the wide intervening ribs have become narrow keels. In Meniscoëssus there are no keels, but the margin of the crown is serrate (Fig. 7 *a c*).

The *Ptilodus mediævus* further differs from the *Neoplagiaulax eocænus* in the more rodent-like character of its incisor teeth. In the latter species these teeth resemble more those of the kangaroos in their anterior direction. The diastema is longer in Ptilodus, thus increasing the rodent resemblance. The fourth premolar is strongly serrate in the Neoplagiaulax, resembling in this also the Mesozoic types.

The discussion between Professor Owen on the one side, and

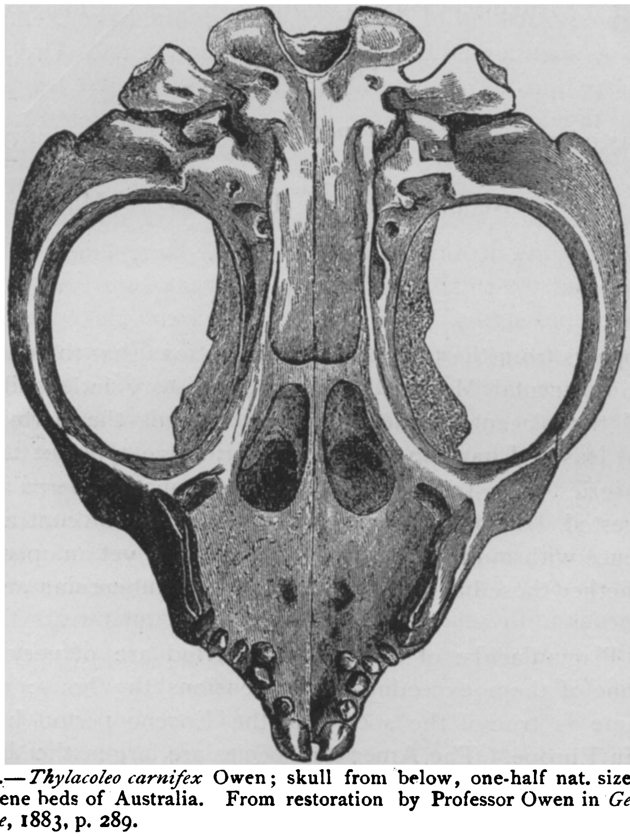


FIG. 9.—*Thylacoleo carnifex* Owen; skull from below, one-half nat. size; from the Pliocene beds of Australia. From restoration by Professor Owen in *Geological Magazine*, 1883, p. 289.

Messrs. Falconer, Krefft and Flower on the other, as to the nature of the food of Thylacoleo, is known to palæontologists. From the form of the teeth alone, Professor Owen inferred the carnivorous nature of the food of this genus, while his opponents inferred a herbivorous diet from the resemblance between the dentition and that of the herbivorous Hypsiprymnus. I have pointed out (*l. c.*) that the comparison of Thylacoleo with Hypsiprimnus

is weakened by two considerations: First, the cutting teeth in the two genera are not homologous; second, the grinding series of molars, complete in Hypsiprymnus, is almost wanting in Thylacoleo. It evidently does not follow that because Hypsiprymnus is herbivorous Thylacoleo is so also. Professor Flower refers to the reduction of the molars in Thylacoleo as slightly complicating the problem, and concludes that the food of that animal may have been fruit or juicy roots, or even meat. It is difficult to imagine what kind of vegetable food could have been appropriated by such a dentition as that of Ptilodus and Thylacoleo. The sharp, thin, serrate or smooth edges are adapted for making cuts and dividing food into pieces. That these pieces were swallowed whole is indicated by the small size and weak structure of the molar teeth, which are not adapted for crushing or grinding anything but very small and soft bodies, It is not necessary to suppose that the dentition was used on the same kind of food in the large and the small species. In *Ptilodus mediævus* the diet may have consisted of small eggs which were picked up by the incisors and cut by the fourth premolars. In *Thylacoleo carnifex* it might have been larger eggs, as those of the crocodiles, or even the weaker living animals. The objection to the supposition that the food consisted of vegetables, is found in the necessity of swallowing the pieces without mastication. In case it should have been of a vegetable character the peculiar premolar teeth would cut off pieces of fruits and other soft parts as suggested by Professor Flower, but that these genera could have been herbivorous in the manner of the existing kangaroos, with their full series of molars in both jaws, is clearly an inadmissible supposition.

——:o:——

VESTIGES OF GLACIAL MAN IN MINNESOTA.

BY MISS FRANC E. BABBITT.

(Continued from page 605, June number.)

THE notch quartzes hitherto examined have been differentiated by marked peculiarities of distribution, worth while to enumerate in this place.

First: as there were originally no quartzes afforded by the soil above the stratum, so there were none yielded by that lying immediately below; although it would naturally be expected that